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Cost, Benefit, and Risk Assessment Guidelines for R,E&D Investment Portfolio Development

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Prepared for the
Program Analysis and Operations Research, ASD-400
and
Research Division, AAR-200
Federal Aviation Administration
800 Independence Avenue, S.W.
Washington, DC 20591

Prepared by the
Operations Assessment Division, DTS-59
Volpe National Transportation Systems Center
55 Broadway
Cambridge, MA 02142

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Preface

This document presents guidelines for conducting benefit, cost, and risk assessments on the Federal Aviation Administration's (FAA's) Research, Engineering and Development (R,E&D) projects. The guidelines are intended to support managing the overall FAA R,E&D investment portfolio and to provide information useful to individual R,E&D project managers.

The original version of the assessment guidelines, *Cost, Benefit, and Risk Assessment Guidelines for R,E&D Investment Portfolio Development*, December 1996, was prepared by James L. Poage of the Operations Assessment Division, DTS-43, and by Paul D. Abramson and Edmund J. Koenke of System Resources Corporation. The work was performed for the Program Analysis and Operations Research Division, ASD-400, and the Office of Research, AAR-200, of the FAA. Frances Melone, Daniel Citrenbaum, Evan Soffer, and Arturo Politano of ASD-400, and Clyde A. Miller and Randall J. Stevens of AAR-200 made major contributions to the guidelines presented.

These guidelines have been updated for October, 1998, by changing the standard values for statistical life, injury, aircraft damage, and aircraft operating costs to reflect the 1998 values provided by the Office of Aviation Policy, and Management Analysis (APO). APO has developed revised guidelines for the economic analysis of investment and regulatory decisions and revised economic values for evaluation of FAA investment and regulatory programs, which are cited in the updated references 1 and 7 in this document. The format of the table of 1998 cost values is taken from the revised APO document (Reference 7).

Cost, Benefit, and Risk Assessment Guidelines for R,E&D Investment Portfolio Development

1.0 Introduction

This document presents guidelines for conducting benefit, cost, and risk assessments on the Federal Aviation Administration's (FAA's) Research, Engineering and Development (R,E&D) projects. Guidelines for assessing benefits, costs, and risks of FAA R,E&D projects are presented in Chapters 2, 3, and 4, respectively. General steps for the assessments are presented as well as tables to serve as check-lists on elements that might be included in the assessments. The benefit and cost assessments are quantitative and the results are expressed in dollars. The risk assessment results are expressed as high, medium, or low ratings of risk.

The benefit and costs steps in this document are intended as guidelines and check-lists to estimate all benefits that are expected to accrue from an R,E&D project and to estimate the costs that are expected to be expended in completing, implementing and operating an R,E&D project. The precise steps listed do not have to be followed as long as the general principles of benefit and cost analyses are followed. The final benefits and costs should be presented as a present value discounted sum of a 20-year stream of annual benefits where all annual benefits are expressed in appropriate constant dollars.

1.1 Changes from December 1996 and November 1997 Versions

The first version of *Cost, Benefit, and Risk Assessment Guidelines for R,E&D Investment Portfolio Development* was dated December 1996, with a revision dated November 1997. The only change in this October 1998 version is that the standard values for such parameters as value of passenger time, statistical life, injury, aircraft replacement cost, and aircraft operating cost have been updated to 1998 dollars. The FAA Office of Aviation Policy Plans, and Management Analysis (APO) has developed revised guidelines for the economic analysis of investment and regulatory decisions and revised economic values for evaluation of FAA investment and regulatory programs, which are cited in the updated references 1 and 7 in this document. The new table, including the new format, of 1998 cost values in this document is taken from the revised APO document (Reference 7).

1.2 Constant Dollars, Present Value, and Standard Dollar Values

The results of all benefit and cost assessments should be expressed in constant dollars, which for this version of the guidelines is 1998 dollars. Standard dollar values for such common factors as value of passenger time, value of a statistical life, value of injury, aircraft replacement costs, and aircraft operating costs are presented in Table 1.1. The Office of Aviation Policy, Plans, and

Management Analysis developed the values based on guidance in Reference 7 and are expressed in 1998 dollars.

The basic approach is to estimate the benefits and costs for each year over a 20 year period (or the life of the project outputs if less that 20 years),

$$B_1, B_2, \ldots, B_n, \ldots, B_{20}$$

$$C_1, C_2, \ldots, C_n, \ldots, C_{20}.$$

B_n and C_n are the benefit and cost estimates for year n expressed in 1998 dollars for all years n = 1 to 20. The steps for estimating these benefits and costs are presented in Chapters 2 and 3.

Once the yearly benefit and cost streams are estimated, the present values are calculated typically using the standard discount rate of 7 percent (based on Reference 4 which can be consulted for more information on discount rates). The total present values are calculated by the following formulae,

$$\text{Total Present Value of Benefits} = \sum_{n=1}^{20} \frac{B_n}{(1+i)^n}$$

$$\text{Total Present Value of Costs} = \sum_{n=1}^{20} \frac{C_n}{(1+i)^n}$$

where i is the discount rate (for the discount rate of 7 percent, the denominator for both formulae is 1+.07 or 1.07). The total present values of benefits and costs are presented in 1998 dollars.

The benefit/cost ratio is,

Benefit/Cost Ratio = (Total Present Value of Benefits)/(Total Present Value of Costs).

As mentioned previously, the values in Table 1.1 were developed by the Office of Aviation Policy, Plans, and Management Analysis based on guidance in Reference 7. The values are sometimes determined for a representative general population of people or equipment. If desired in a detailed analysis where benefits or costs are being estimated for a specific population subset of people or equipment, the guidance in Reference 7 can be followed to develop values for that particular population subset. In such a case, the values developed for the particular population subset may be used even though they may be different than those listed in the above tables. The values should be expressed in 1998 dollars for results presented with the use of this version of the guidelines.

Reference 7 lists economic values for more detailed subsets of aircraft and other factors than are expressed in Table 1.1. The reference can be consulted for such more detail values if needed, such as operating costs of aircraft with a specific number of jet engines.

Table 1.1 - Economic Values for Use in Analyses Conducted in 1998 Dollars

Physical Unit	Value
Value of Passenger Time per Hour	
Air Carrier:	
Personal	$19.50
Business	$34.50
All Purposes	$26.70
General Aviation:	
Personal	$26.30
Business	$37.50
All Purposes	$31.10
Avoided Fatality	$2,700,000.
Avoided Injuries	
Injury Value by AIS Category (per injury):	
Minor (AIS-1)	$5,400.
Moderate (AIS-2)	$41,900.
Serious (AIS-3)	$155,300.
Severe (AIS-4)	$506,300.
Critical (AIS-5)	$2,058,800.
Fatal after 30 Days (AIS-6)	$2,700,000.
Other Costs by AIS Category (per victim):	
Minor (AIS-1)	$2,300.
Moderate (AIS-2)	$6,300.
Serious (AIS-3)	$18,800.
Severe (AIS-4)	$99,200.
Critical (AIS-5)	$266,200.
Fatal after 30 Days (AIS-6)	$119,000.
Injury and Other Costs by ICAO Category (per victim):	
Minor	$38,500.
Serious	$521,800.

Table 1.1 - Economic Values for Use in Analyses Conducted in 1998 Dollars (cont'd)

Physical Unit	Value
Aircraft Capacity and Utilization Factors	
Scheduled Commercial Service:	
Passenger Capacity	162.3 seats
Crew Size	6
Cargo Capacity	11.6 tons
Passenger Load Factor	70.7%
Cargo Load Factor	44.6%
Daily Utilization	6.9 hours
Average Flight Speed	417 mph
Air Carriers w/o Commuters:	
Passenger Capacity	168.7 seats
Crew Size	6.1
Cargo Capacity	12.2 tons
Passenger Load Factor	71.0%
Cargo Load Factor	44.6%
Daily Utilization	7.4 hours
Average Flight Speed	439 mph
Commuters Only:	
Passenger Capacity	30.6 seats
Crew Size	3
Cargo Capacity	1.6 tons
Passenger Load Factor	52.3%
Cargo Load Factor	33.1%
Daily Utilization	4.5 hours
Average Flight Speed	232 mph
Air Taxi:	
Passenger Capacity	6.6 seats
Passenger Load Factor	44.4%
Useful Load	3,097 lbs.
General Aviation Only:	
Passenger Capacity	5.4 seats
Passenger Load Factor	49.5%
Useful Load	1,894 lbs.
General Aviation and Air Taxi:	
Passenger Capacity	5.5 seats
Passenger Load Factor	49.0%
Useful Load	1,969 lbs.

Table 1.1 - Economic Values for Use in Analyses Conducted in 1998 Dollars (cont'd)

Physical Unit	Value
Aircraft Operating Costs	
Scheduled Commercial Service:	
Variable Operating Cost per Hour	$2,448.
Fixed Cost per Hour	$645.
Total Cost per Hour	$3,093.
Air Carrier w/o Commuter:	
Variable Operating cost per Hour	$2,876.
Fixed Cost per Hour	$727.
Total Cost per Hour	$3,603.
Commuters Only:	
Variable Operating Cost per Hour	$572.
Fixed Cost per Hour	$276.
Total Cost per Hour	$848.
Air Taxi:	
Variable Operating Cost per Hour	$424.
Fixed Cost per Hour	$356.
Total Cost Per Hour	$780.
General Aviation Only:	
Variable Operating cost per Hour	$190.
Fixed Cost per Hour	$375.
Total Cost per Hour	$565.
General Aviation and Air Taxi:	
Variable Operating cost per Hour	$303.
Fixed Cost per Hour	$373.
Total Cost per Hour	$677.
Military: Variable Operating Cost per Hour	$1,631.

Table 1.1 - Economic Values for Use in Analyses Conducted in 1998 Dollars (cont'd)

Physical Unit	Value
Replacement Costs of Destroyed Aircraft	
Scheduled Commercial Service	$16,300,000.
Air Carriers w/o Commuters	$19,480,000.
Commuters Only	$3,740,000.
Air Taxi	$665,000.
General Aviation Only	$522,000.
General Aviation and Air Taxi	$532,000.
Military	$21,600,000.
Restoration Costs of Damaged Aircraft	
Scheduled Commercial Service	$2,200,000.
Air Carriers w/o Commuters	$2,630,000.
Commuters Only	$501,000.
Air Taxi	$143,000.
General Aviation Only	$133,000.
General Aviation and Air Taxi	$133,000.
Military	$2,920,000.

2.0 Benefits Assessment Guidelines

Benefit estimates of a particular course of action (e.g., to implement a new system that replaces an existing system) must always be measured incrementally (or marginally) against a baseline, which is the situation that would exist if the particular action were not performed. The baseline would be what happens if the existing system continues to be operated. It does not contain the new system, regulation, or other product under development. For R,E&D projects, the benefit estimates then must deal with estimating the changes in systems or operating environments from implementing the results of the R,E&D project as compared to what would have happened without the R,E&D project. Benefits that would result from continuing the current situation and would occur even if the R,E&D were not conducted should not be included. This includes comparing operations with and without the R,E&D for all years the new system would be in operation.

Nine benefit estimation guideline tables, Tables 2.1 through 2.9, are presented for the following types of benefits:

(1) Safety - The impacts of increasing the safety to passengers, air crews, aircraft, property, and the general public. This includes preventing: incidents and accidents; death and injury to passengers and operations personnel; damage and destruction to aircraft and equipment; and reduction of errors that might lead to accidents or incidents. Safety is differentiated from security as the incidents are the consequence of untended physical or human failure or environmental (e.g., weather) phenomena.

(2) Security - The impacts of improving security in aircraft/airport operations or in FAA facilities, communications, or data. This includes preventing: bombings, highjackings, computer intrusion, and terrorist actions; and reducing deaths, injuries, damage, adverse consequences, and destruction due to these. Security is differentiated from safety in that the incidents are intentionally caused by terrorist or criminal elements.

(3) Delay - The time and dollars saved due to decreasing delays in the system. This includes decreasing: flight delays/diversions and gate/taxi holds. This includes impacts on passengers, crews, FAA, and others.

(4) User Efficiency - The time and dollars saved due to changes in the operation of the NAS that result in more efficient user operations. This category is distinguished from the delay benefit category above. It includes the impacts on users of the air transportation system, such as air carriers, commuter air operators, general aviation, and the military, through improvements in air routes, fuel saving operations, and changes in procedures and regulations which result in the saving of time and personnel costs. An example of user efficiency would be a project that results in the ability to fly at more fuel efficient altitudes, hence achieving greater fuel efficiency.

(5) User Capital Costs Avoided - The capital dollars saved or spending avoided by users of the air transportation system. This includes all expenditures for equipment, aircraft, and facilities (i.e., capital costs) by users which can be avoided or deferred because of changes to the operations, procedures, and rules of the air transportation systems as a result of an R,E&D program.

(6) FAA Operations and Maintenance (O&M) Productivity - Benefits that the FAA receives in terms of increased productivity of FAA operations and maintenance personnel. This includes avoided personnel growth caused by enhancing operations within the FAA and includes impacts on training, management, certification, and operations work.

(7) FAA Capital Costs Avoided - The capital dollars (i.e., F&E) saved or spending avoided by the FAA. Again, capital costs avoided or deferred include one-time acquisition costs of equipment and facilities. This includes facilities/buildings and all equipment including navigation, surveillance, automation, and communications.

(8) Developing Enabling Technologies - R,E&D programs are often undertaken that are either exploratory in nature or develop capabilities that the FAA or industry need to successfully continue other enhancements to the air transportation system. This includes positive impacts that the R,E&D program has upon subsequent programs or activities that in turn directly impact the development and operations of the system that generate measurable benefits. This may involve improved procedures, rules, and training because of new, enabled, or transferred technology. It is usually difficult to predict future outputs of such programs, and, thus, difficult to quantify the benefits of conducting the programs. However, efforts must be made to identify and quantify the impacts that the R,E&D program has upon subsequent programs or activities that directly impact the development and operation of the system and, thus, generate measurable benefits.

(9) Society - Benefits that accrue to the society in general. These often deal with macroscopic benefits that relate to societal goals, such as reduced fuel consumption and improved quality of life. The benefits to society often derive from one or more of the first eight benefit categories, are often non-monetary, and are often require unique quantification techniques.

Tables 2.1 through 2.9 present metrics for expressing benefits in each benefit category. The metrics are usually expressed in present value dollars which are calculated using the standard discount rate of 7 percent (based on Reference 4 which can be consulted for more information on discount rates). The tables also list intermediate parameters and possible causal factors that will result in a benefit. The intermediate parameters are suggestions for intermediate impacts to estimate before the final conversion to present value dollars. Related causal factors are listed as check lists of benefit impacts to consider. Methodology guidelines for calculating the metrics are also presented in Tables 2.1 through 2.9. The methodology guidelines are in the form of consecutive steps for estimating the benefits.

The benefits from the R,E&D projects do not normally accrue to the FAA, users, or to society until the results of the R,E&D go through development, implementation, and operation. The benefits estimated should, therefore, be those that will accrue assuming the results of the R,E&D go through these stages and the final product is in operation.

<u>The tables should be used as guidelines and check-lists to estimate all benefits that are expected to accrue from the R,E&D project. Only the table or tables that relate to possible benefits from the project under consideration need be used.</u> It is not expected that all guidelines can be followed or all benefits can be calculated. But, all possible benefits should be examined and estimated where possible. Where it is not possible to quantify the benefits, the benefits should be described as completely as possible, again using the tables as a guide for types of benefits. At the very least, the extent of the problem which the R,E&D project will mitigate should be quantified.

The guidelines are brief and provide only an outline for benefit estimation. While they may appear self-evident, the guidelines are presented to assure consistency in the estimation of benefits across R,E&D projects. More details on benefit estimation methodologies and data sources can be found in references listed in Appendix A. These data sources are particularly useful for standard values of parameters used to estimate benefits, such as value of a fatality, injury, or aircraft damage, and future air traffic forecasts. References for such data values are listed in the first table in Appendix B. Models and data bases that may be useful are briefly described in the Databases and Models sections after the references.

In presenting the results of the benefit analysis, the present values of benefits should be presented for each relevant category represented by Tables 2.1 through 2.9, along with the sum of present value of benefits across all categories. In addition, constant dollar benefit values for each of the nine relevant categories and total across categories should be presented for each future year for 20 years or project life, whichever is less.

2.1 Safety Benefits

Table 2.1 - Safety Benefits

Metric	Intermediate Parameters to Quantify Metric	Related Causal Factors to Consider
• Value of fatalities avoided • Value of injuries avoided • Value of aircraft damage/destruction avoided • Value of property damage avoided • Value of accident investigation costs avoided	• Number of : – Accidents avoided ∗ Fatalities avoided ∗ Injuries avoided ∗ Aircraft damage avoided ∗ Aircraft destruction avoided ∗ Property damage avoided • Accident investigation costs avoided (e.g., NTSB investigations) • Assess impacts for – Air carrier – Commuters and air taxi – General aviation – Military	• Reduced pilot errors • Reduced controller errors • Reduced aircraft equipment failures • Reduced problems with airport conditions • Reduced weather caused accidents[1] • Reduced runway incursions • Mitigation of impacts if an accident does occur (reduced accident severity impacts on passengers, crew, aircraft, property, other)

Safety Benefits Estimation Methodology
1. Estimate how many accidents are attributed to the problem this R,E&D project will solve. 2. Estimate changes in exposure to accidents, due to implementing results of R,E&D program. Exposure estimates should account for appropriate accident exposure measures. For the en route components of a flight, accident exposure measures related to flight duration are appropriate, such as hours flown or miles flown. For en route turbulence accidents, a measure such as passenger-miles is acceptable since the chances of at least one passenger being affected by turbulence is greater with more passengers. The non-en route components of a flight occur primarily in the terminal area, and a potential accident exposure measure in the terminal area is number of operations. 3. Estimate decrease in percent of accidents, or severity of accidents for projects that will mitigate the severity of accidents. Use: – models or analysis of percent accidents prevented (or percent decline in severity of accidents that occur), or – expert judgment on percent of accidents prevented. 4. Estimate decrease in number of accidents, fatalities, injuries, and damage in current year using percent decrease in accidents (or percent decrease in accident severity) and current year or average of recent year data on number of accidents and on fatalities, injuries, and damage. 5. Estimate future year decrease in number of accidents, fatalities, injuries, and damage using projections in aircraft and passenger traffic through life of project or 20 years, whichever is less. 6. Calculate estimated dollar value of all accidents avoided (or all accident severity mitigation) each year using specified constants for value of life, injuries, and damage. 7. Calculate estimated present value of accidents avoided (or accident severity mitigated) using specified discount rate(s). Note: Where appropriate, incidents not resulting in accidents but which are estimated to be avoided may be presented descriptively.

[1] Potential weather associated accident causes include: turbulence, icing, thunderstorms, tornadoes, hurricanes, windshear, visibility/ceiling, and wind.

2.2 Security Benefits

Table 2.2 - Security Benefits

Metric	Intermediate Parameters to Quantify Metric	Related Causal Factors to Consider
• Value of fatalities avoided • Value of injuries avoided • Value of aircraft damage/destruction avoided • Value of property damage or other damage avoided • Value of cost reduction for airlines and/or airports to provide security • Value of incident investigation costs avoided • Value of incidents prevented on FAA facilities or information systems • Value of cost reductions in providing security for FAA	• Number of : – Incidents avoided ∗ Fatalities avoided ∗ Injuries avoided ∗ Aircraft damage avoided ∗ Aircraft destroyed avoided • Property damage or other costs avoided • Reduction in airline and/or airport costs to provide security measures • Incident investigation costs avoided • Security measures provided at lower cost • Reduction in security impacts on FAA facilities or information systems • Reduction in costs to FAA to provide security measures • Assess impacts for – Aircraft ∗ Air carrier ∗ Commuters and air taxi ∗ General aviation ∗ Military – Airports – FAA facilities and information systems	• Bombings prevented or severity reduced • Hijackings prevented or severity reduced • Other incidents prevented or severity reduced • Cost reductions in providing airline or airport security • Incidents prevented on FAA • Cost reductions in providing security for FAA

Security Benefits Estimation Methodology
1. Estimate how many accidents and incidents are attributed to the problem this R,E&D project will solve. For this step and in steps 2, 3, and 4 below, sources of information include US history of security incidents, history of security incidents in foreign countries, security experts, and threat analysis. 2. Estimate changes in exposure to incidents (incidents include bombings and hijackings) due to implementing results of R,E&D program.[2] 3. Estimate decrease in percent of incidents. 4. Estimate decrease in number of incidents, fatalities, injuries, and damage in current year using percent decrease in incidents and current year or average recent years' data on number of incidents, fatalities, injuries, and damage. Also, estimate reduction in airline and/or airport costs to provide security measures in current year. 5. Estimate future year decrease in number of incidents, fatalities, injuries, and damage using projections in aircraft and passenger traffic through life of project or 20 years, whichever is less. Also, estimate future year reductions in airline and/or airport costs to provide security measures using projections in aircraft and passenger traffic through life of project or 20 years, whichever is less. 6. Calculate estimated dollar value of all incidents avoided each year using specified constants for value of life, injuries, and damage. Also, apply any specified constants for airline and/or airport costs to estimate future year reductions in airline and/or airport costs to provide security measures. 7. Calculate estimated present value of incidents avoided and reductions in airline and/or airport costs to provide security measures using specified discount rate.

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[2] Incidents are rare events and may not occur annually. Use rate of occurrence where available. If not available, it may be necessary to use past incident(s) as example of amount of damage that can be prevented.

2.3 User Delay Benefits

Table 2.3 - User Delay Benefits

Metric	Intermediate Parameters to Quantify Metric	Related Causal Factors to Consider
• Value of passenger time saved • Value of aircraft operating cost saved	• Number of flights with reduced delays • Number of canceled flights reduced • Number of diverted flights reduced • Total aircraft operating time/cost saved from reduced delays • Number of passengers with reduced delays • Total passenger time saved with reduced delays • Assess delay reductions for – Flights * En route * Ground * Terminal – Canceled flights – Diverted flights • Assess impacts for – Air carrier – Commuters and air taxi – General aviation – Military	• Reduced weather caused delays – Take-off delays due to poor visibility snow, winds, etc. – Weather diversions • Decreased separations due to wake vortex mitigation • Reduced controller workload induced delays • Increased capacity which reduces delays during heavy traffic • Reduced use of lower capacity procedures due to equipment outages

User Delay Benefits Estimation Methodology
1. Estimate the delay in current year and in the future attributable to the problem this project will address. 2. Estimate increase in specific system performance attributes affected by implementing results of R,E&D program.[3] 3. Estimate impact of system performance upon operational parameters (e.g., aircraft separation) and hence on delay. If increased demand for air travel is expected from the delay reduction, this increased demand can be described anecdotally. 4. Estimate value for users of reduction in delay in current year. In steps 4, 5, and 6, the dollar value benefit of reduced delays should be calculated both with and without including the value of passenger time saved. 5. Project value of delay reduction into future years using projections of future year operations. Develop such projections of benefit estimates annually through life of project or 20 years, whichever is less. 6. Calculate estimated present value using specified discount rate.

(Note: User delay includes reductions in traditional delays. It does not include flight time reductions and other cost savings due to more efficient user operations.)

[3] Methodology is generic, but benefits may be specific to locations where implemented. Use specific locations if known, and Terminal Area Forecasts for these locations. If locations are not known, make assumptions on number of sites to be implemented. Use the maximum potential number of sites that is reasonable. If benefits are location specific, identify a list of potential reasonable sites.

2.4 User Efficiency Benefits

Table 2.4 - User Efficiency Benefits

Metric	Intermediate Parameters to Quantify Metric	Related Causal Factors to Consider
• Value of passenger time saved • Value of user operating cost saved	• Number of flights with reduced flight time • Number of passengers with reduced flight time • Total passenger time saved with reduced flight time • Total aircraft operating time/costs saved from reduced flight time • Total other user operational time/cost saved • Assess efficiency benefits for en route, ground, terminal, canceled flights, diversions • Assess impacts for – Air carrier – Commuters and air taxi – General aviation – Military	• Use of more direct routes • Use of more fuel efficient routes • Aircraft enhancements using less fuel • Change in user procedures to utilize new FAA facilities or ATC procedures • Change or new FAA regulations that reduce requirements on user procedures and personnel time (e.g., change in size or composition of crew)

User Efficiency Benefits Estimation Methodology
1. Define the inefficiency(ies) that this project will address. 2. Estimate increase in specific user performance attributes affected by implementing results of R,E&D program. 3. Estimate impact of user performance change upon user operational parameters (e.g., reduction in aircraft fuel usage). 4. Estimate total dollar value of change in operational parameters in current year. In steps 4, 5, and 6, the dollar value benefit of reduced delays should be calculated both with and without including the value of passenger time saved. 5. Project value of change into future years using projections of future year operations. Develop such projections of benefit estimates annually through life of project or 20 years, whichever is less. 6. Calculate estimated present value using specified discount rate.

(Note: User Efficiency does not include reductions in traditional delays. It includes flight time reduction, fuel savings, and other cost savings due to more efficient user operations)

2.5 User Capital Costs Avoided

Table 2.5 - User Capital Costs Avoided

Metric	Intermediate Parameters to Quantify Metric	Related Causal Factors to Consider
• Value of user cost savings for aircraft and equipment	• Change in aircraft/equipment due to new or changed FAA facilities, procedures, regulations, or economic circumstance related to FAA actions • Assess impacts for − Air carrier − Commuters and air taxi − General aviation − Military	• New or changed FAA facilities, regulations, or procedures and their requirements on user aircraft and equipment

User Capital Costs Avoided Estimation Methodology
1. Identify aircraft and equipment that R,E&D project will affect through utilizing new FAA facilities or procedures or from complying with resulting FAA regulations. 2. Assess changes in aircraft and equipment resulting from R,E&D project. 3. Estimate dollar value in constant dollars of the changes in aircraft and equipment in year(s) they are expected to occur. Use projections on future number of aircraft or flight activity as appropriate. Develop such benefit estimates annually through life of project or 20 years, whichever is less. 4. Calculate estimated present value using specified discount rate.

2.6 FAA Operations and Maintenance (O&M) Productivity Benefits

Table 2.6 - FAA Operations and Maintenance (O&M) Productivity Benefits

Metric	Intermediate Parameters to Quantify Metric	Related Causal Factors to Consider
• Value of avoided FAA personnel costs – air traffic – operations and maintenance – regulatory inspection and enforcement • Value of other reduced facility/equipment operating and maintenance costs	• Avoided staffing costs through efficiencies in handling growth in air traffic • Reduced equipment corrective maintenance times and avoided costs • Reduced equipment periodic maintenance times and avoided costs • Reduced regulatory inspection and enforcement time and avoided costs • Reduced training time and avoided costs • Reduced need for spare parts • Reduced communication costs • Reduced facility utility costs • Reduced facility rent costs	• Increased controller efficiency in handling growth in air traffic • Reduced periodic maintenance requirements • Reduced failures • Reduced number of or time for inspection and enforcement • Reduced spares costs from higher equipment reliability • Reduced communications requirements • Reduced utility requirements • Reduced facility requirements

FAA Operations and Maintenance (O&M) Productivity Benefit Estimation Methodology
1. Assess impacts due to implementing results of R,E&D program in FAA operations. 2. Estimate value of productivity impacts in current year. 3. Project estimated value of productivity impacts into future years using projections of future aircraft operations and future FAA equipment capabilities. Develop such projections of benefit estimates annually through life of project or 20 years, whichever is less. 4. Calculate estimated present value using specified discount rate.

2.7 FAA Capital Costs Avoided

Table 2.7 - FAA Capital Costs Avoided

Metric	Intermediate Parameters to Quantify Metric	Related Causal Factors to Consider
• Value of capital investment costs avoided or deferred	• Reduced capital investment costs for new equipment • Reduced costs from deferring the need for new equipment	• Reduced development and/or implementation costs for new equipment • Cheaper replacement alternatives – COTS/NDI – non-capital investment alternative

FAA Capital Costs Avoided Estimation Methodology
1. Assess changes in FAA capital investment costs for new equipment and from deferring the need for new equipment. 2. Estimate dollar value in constant dollars of changes in FAA equipment for the year(s) in which they are expected to occur. Use projections of future year operations as necessary. Develop such benefit estimates annually through life of project or 20 years, whichever is less. 3. Calculate estimated present value using specified discount rate.

2.8 Enabling Technologies

Table 2.8 - Enabling Technologies[4]

Metric	Intermediate Parameters to Quantify Metric	Related Causal Factors to Consider
• Quantified cost, schedule, or risk reductions in other programs • Improved analysis capabilities • Improved test and evaluation capabilities	• Results used in other programs – Enhanced implementation or effectiveness of other programs – Cost, schedule, or risk reduction in other programs – Analysis results published – Tests and evaluations conducted	• Causal factors from all other benefit categories (Table 2.1 through 2.7 and 2.9) should be considered

Enabling Technologies Estimation Methodology
1. Identify operations, capital improvements, or other R,E&D or F&E projects that the particular R,E&D project will enable. 2. Identify the nature of the impact of the particular R,E&D project (e.g., enhance implementation, efficiency of use, or introduction of new technologies into other projects; reduce cost, schedule, or risk for other projects; provide analysis or simulation tools to enhance design and decision-making on other projects; and provide better testing and evaluation of other projects). 3. Estimate magnitude of these impacts on other projects. If possible, express impacts in dollars. 4. Project value of change into future years using projections of future year operations. Develop such projections of benefit estimates annually through life of project or 20 years, whichever is less. 5. Calculate estimated present value using specified discount rate.

[4] Enabling technologies include R,E&D programs that are either exploratory in nature or develop capabilities that the FAA or industry need to successfully continue enhancements to the air transportation system. Examples of such programs are simulation capabilities, some human factors programs, and some university programs. While it is often difficult to define specific outputs and quantify impacts of such R,E&D since they do generate direct benefits, efforts should be made to identify and quantify the impact that the R,E&D program has upon subsequent programs. At the very least, the way results of the R,E&D project will be used by subsequent programs should be described. An effort should be made to express this use quantifiably, such as number of programs that will use new simulation capabilities and time and resources the use of the new simulation capabilities are expected to save on these subsequent programs. If possible impacts should be described in present value dollars.

2.9 Society Benefits

Table 2.9 - Society Benefits

Metric	Intermediate Parameters to Quantify Metric	Related Causal Factors to Consider
• Noise exposure reduction • Air quality improvement • National energy use reduction[5]	• Change in noise levels from aircraft • Change in noise exposure to population • Reduced air pollutant emissions • Reduced fuel use by aircraft[9] • Assess impacts for – Air carrier – Commuters and air taxi – General aviation – Military	• Change in aircraft noise emissions • Change in flight paths leading to changes in exposure of population to noise • Change in noise mitigation in structures housing people • Change in air pollutant emissions • Change in fuel consumption by enhanced engines or airframe[9] • Change in fuel consumption by less delay[9]

Society Benefits Estimation Methodology
1. Estimate changes in parameters affected by R,E&D, such as noise levels, air pollution emissions, and fuel use.[6] 2. Estimate change in impacts on general population, such as noise exposure, air quality improvement, and energy use reduction. 3. Estimate number of persons affected, total health impacts, and total economic value for one year. 4. Estimate future year changes using projections of flight traffic, populations, and economic activity through life of project or 20 years, whichever is less. 5. Estimate total population impacts over life of project or twenty years, whichever is less, and total economic present value of impacts using specified discount rate.

[5] Dollar savings from decreased fuel usage were addressed in User Efficiency Benefits, Table 4. Under Societal Benefits, reduction in energy consumption is considered as a national benefit. This may be the same energy consumption estimated as dollar savings under User Efficiency Benefits, but under Societal Benefits it should be expressed as barrel of oil saved or some other volume of energy measure.

[6] Societal benefits may be difficult to quantify. An attempt should be made first to assess impacts on a per aircraft basis, such as noise reduction from an aircraft, air pollution emissions reductions from an aircraft, and reduction in fuel consumption in an aircraft. These impacts on a per aircraft basis then should be summed for relevant aircraft population in future years. If possible, at least the size of population affected annually for noise and air pollution benefits should be estimated.

3.0 Cost Assessment Guidelines

Cost estimation is the process of identifying elements of cost and then quantifying (or estimating) them. Cost risks will not be discussed in this section; they will be discussed in Section 4.0. As with benefits, the cost estimates should be incremental costs against a baseline, which is the situation that would exist if the particular action being evaluated were not performed. The baseline does not contain the system, regulation, or other product under development. A complete R,E&D cost estimate includes not only the cost for the R,E&D phase but also costs for implementing the new system and changes in operating costs after implementation as compared to what the costs would have been for the situation without the R,E&D project. This includes comparing costs with and without the R,E&D for all years the new system would be in operation. Thus, cost estimates of implementing the results of the R,E&D project include all life-cycle costs (i.e., FAA: R,E&D, F&E, O&M, and Termination; and Users: capital and operational) required to perform the R,E&D and to implement and subsequently operate and maintain the R,E&D results.

Particular care is required in estimating the costs and benefits of a project whose primary purpose is to decrease O&M costs, either through equipment replacement or new rules, regulations, procedures, or operational practices. In this case, the cost savings of a course of action, whether to users or the FAA, is counted on the benefits side of the equation. That is, one attributes as a benefit any savings in O&M costs that accrue from an expenditure (cost) in R,E&D and F&E. The important thing is to make sure the cost saving benefits of an action are properly and uniquely captured.

Described below are FAA Costs, User Costs, and Industry/Other Costs related to bringing the R,E&D project to completion and into operation. The total cost estimates for each of these three type of costs should be stated along with the following information for each type of cost:

(1) FAA Costs - Describe FAA costs by fiscal year that will be required to complete the program (or regulation) and bring it into operation (or use). The total costs for R,E&D, F&E, and O&M should be presented separately. For R,E&D and F&E costs, a five-year breakout of costs from FY 1999 through FY 2003 should be provided with all costs beyond FY 2003 aggregated and recorded in a column, "Outyears." In addition, provide annual operation and maintenance funding requirements. Also, the present value of R,E&D, F&E, and O&M costs should each be presented using the specified discount rates (Reference 4) for the life of the project or 20 years, whichever is less.

(2) User Costs - Describe the user community investment requirements by fiscal year including each user category (i.e., air carrier, commuters and air taxi, general aviation, and military). Also, divide costs into voluntary and mandatory where mandatory are required by regulation. The present value of all user costs should be presented using the specified discount rate of 7 percent (7 percent is based on Reference 4 which can be consulted for more information on discount rates) for the life of the project or 20 years, whichever is less.

(3) Industry/Other Costs - Describe the costs by fiscal year required from industry (other than the flying public and air transport industry involved in flying airplanes which is captured under user costs) and/or other agencies (e.g., NASA, DOD, and airport authorities) to carry the program to completion and into operations (e.g., system development, procedure development, rule making). Identify who will be required to make the investment, and whether the investment is mandatory or voluntary. The present value of all industry and other agency costs should be presented using the specified discount rate of 7 percent (Reference 4) for the life of the project or 20 years, whichever is less. Where DOD costs are those as a user, rather than for development or implementation, such costs are covered under user costs in the previous section.

The two steps of the cost estimation process, Cost Identification and Cost Quantification, are described below. The methods and tables should be used as guidelines and check-lists to estimate all costs that are expected to complete the R,E&D project and complete the life-cycle of the project results. Only the cost elements that relate to the project under consideration need be used. It is not expected that all guidelines can be followed or all costs can be calculated, but all costs should be identified and estimated where possible. Where it is not possible to quantify the costs, the costs should be listed and described as completely as possible, again using the tables as a guide for elements.

The guidelines are brief and provide only an outline for cost estimation. While they may appear self-evident, the guidelines are presented to assure consistency in the estimation of costs across R,E&D projects. More details on cost estimation methodologies can be found in the references listed in Appendix A. Models and data bases that may be useful are briefly described in Appendix.

3.1 Cost Identification - Step 1

Cost Identification is the first step in the cost estimation process. The cost elements to be considered in the cost analysis are listed in Tables 3.1a, 3.1b, and 3.2.[7] The program phases and cost elements in the tables are meant to provide guidance in identifying appropriate elements so that the cost analyses are complete and consistent across projects. Only those cost elements that apply to a specific project need be included in the cost analysis. Cost elements should include costs for personnel (technical, management, administrative), hardware, software, facilities, and consumables. They should include all costs incurred by the FAA, contractors that develop systems for the FAA, and users that are impacted by the FAA system or regulation.

A distinction is made between R,E&D projects that result in a major system acquisition (i.e., capital acquisition programs) versus projects that result in a new rule or regulation (i.e., regulatory programs). The steps required to develop, implement, operate, and maintain a system are different from the steps required to develop, promulgate, enforce, and monitor a rule or regulation. Table 3.1a describes the FAA costs associated with capital acquisition programs. Each of the phases or steps in the Major System Acquisition Process is identified with a set of cost elements and/or activities that contribute to the overall cost of the acquisition phase. The

[7] The contents of these tables were derived based on the *FAA Program Manager's Guide*, April 1994.

total life-cycle cost is estimated by calculating the costs associated with each phase of the acquisition process and then summing over all acquisition phases.

Table 3.1b describes the FAA costs associated with a regulatory program. As previously stated, these steps or phases are different from the phases of a major system acquisition. However, the structure of the table is similar and a set of cost elements and/or activities that contribute to the overall cost of each phase of the regulatory development process are identified. As before, the total life-cycle cost of a regulatory program is estimated by calculating the costs associated with each phase of the regulatory process and then summing over all phases.

The cost elements to be considered for user costs are listed in Table 3.2.

Tables 3.1a, 3.1b, and 3.2 can also be used as checklists for cost elements that might apply to industry or other agencies.

Table 3.1a - FAA Costs for Acquisition Programs

Program Phase	Cost Elements/Activities
Mission Needs Determination	• Data collection and analysis • Mission needs analyses • Mission needs statements • Organize and staff program
Concept Exploration and Alternatives Analysis	• Identify capital and non-capital alternatives • Identify design approaches • Perform technology assessments • Develop program plans
Demonstration, Validation, or Acquisition Execution	• Program management • Proof of concept • Prototype design and development • Testing and analysis • Reporting and documentation
Full Scale Development	• Program management • System design and development • Testing and analysis • Reporting and documentation
Production and Deployment	• Program management • Land acquisition • Facilities acquisition/modification • Equipment production • Equipment transportation • Support equipment • Installation and testing • Logistic support planning • Initial spares • Acceptance testing • Operations and maintenance training • Reporting and documentation
Operation and Maintenance	• Personnel costs (controller, maintenance, inspection, other) • Consumables • Replenishment spares • Energy and utilities • Real property leases • Equipment leases • Recurring training • Recurring travel • Telecommunications
Termination	• Dismantling costs • Transportation and packaging • Environmental audits • Site restoration and disposal • Storage and materiel management

Table 3.1b - FAA Costs for Regulatory Programs

Program Phase	Cost Elements/Activities
Mission Needs Determination	• Data collection and analysis • Mission needs analyses • Mission needs statements • Organize and staff program
Concept Exploration and Alternatives Analysis	• Identify non-capital alternatives • Identify design approaches • Develop program plans
Demonstration or Validation	• Develop pilot testing procedures, rules, or regulations • Pilot testing and analysis • Reporting and documentation
Regulatory, Procedure, and Rule Development	• Perform cost/benefit analysis • Draft Advanced Notice of Proposed Rulemaking (ANPRM), procedure or regulation • Promulgate and coordinate ANPRM, procedures, regulations • Conduct and document hearings • Reconcile comments
Regulatory, Procedure, and Rule Promulgation	• Prepare and issue final regulation, rule or procedure • Set up systems to evaluate impacts
Enforcement	• Enforcement staff • Enforcement systems and data
Termination	• Monitor and terminate if appropriate

Table 3.2 - User Costs

Program Phase	Cost Elements/Activities
Equipment Acquisition and Installation	• Aircraft • Avionics • Engine • Hardware • Software • Communications • Testing • Documentation • Engineering • Installation • Maintenance equipment
Prepare for Regulatory Compliance	• Develop manuals • Perform training for ground or flight personnel • Establish oversight • Documentation
Operations and Maintenance	• Labor (ground or flight personnel) • Spares • Other aircraft and facility operating costs • Additional oversight expenses

3.2 Cost Quantification - Step 2

Cost Quantification is the second step in the cost estimating process where cost values are assigned to the cost elements identified in Step 1, Cost Identification. Methodologies are suggested in this document to determine the cost of conducting an R,E&D program and subsequent life-cycle costs that extend beyond the R,E&D phase. Some sources of estimates for individual cost elements are expert opinion, analogous systems, cost handbooks, and cost models.

Two potential cost estimation approaches are described in this section. FAA Order 1810.3, *Cost Estimation Methodology*, identifies several cost quantification methods (Analogy, Parametric, Component Part/Industrial Engineering, and Vendor Bid) that are recommended for use in performing the cost estimations. For the early acquisition phases, of which R,E&D is representative, the Parametric Method and the Analogy Method are particularly appropriate. Short descriptions of these two methods are provided below.

(1) Analogy Method . This method uses analogy comparisons and lessons learned to estimate costs. These techniques are based on the idea that no new program, no matter how advanced or unique, represents a totally new system or approach. Most "new" programs originated or evolved from already existing programs or simply represent a new combination of existing components or sub-systems. A logical extension of this premise is that key insights can be gained concerning a current program's cost by examining the successes, failures, problems, and solutions of similar existing or past programs. The experience and knowledge gained, or "lessons learned," can be applied to identifying potential costs in a program and developing a strategy to manage and monitor them, particularly the high-cost elements.

The analogy comparison and lesson learned techniques involve the identification of past or existing programs that are similar to the current program being analyzed. The analogy may be similar technology, function, acquisition strategy, manufacturing process, etc. The key is to understand the relationship between the characteristics of other programs and the particular aspects of the current program being examined. For example, in many previous system developments, cost shows a strong positive relationship with technical complexity, thus when looking for a program in which to analyze cost for comparison, it makes sense to examine data from programs with similar function, technology, and technical complexity. The use of data or lessons learned from past programs may be applicable at the system, subsystem or component level. For example, although an existing system's function and quantity produced differ, its processor component may be similar in performance characteristics to a current program which would be a valid basis for analogy comparison. However, caution must be exercised since in most of the FAA's high technology areas, costs often are changing (usually decreasing) rapidly. Several different programs may be used for comparison to the current project at various points along the development cycle of the end item.

(2) Parametric Method. The parametric method uses a mathematical equation to relate cost as a dependent variable to one or more independent variables representing cost or

non-cost characteristics of the system. A cost-to-cost relationship example is using the cost to develop a prototype system (independent variable) to estimate the cost of the initial production system (dependent variable). A classic cost-to-non-cost example is the estimating the cost of an aircraft (dependent variable) by using its planned weight (independent variable). The parametric method is normally utilized at the early stages of a program, when there is limited program and technical definition. This method involves collecting relevant historical data at an aggregated level of detail. Because parametric methods typically capture cost at a very high level, normally less detail is required for this approach than for other methods. The equation can estimate a percentage of some other cost, such as the costs of spare parts might be estimated as a percentage of the total systems cost which is based on the past history of similar system's costs and their respective spare parts costs.

For R,E&D programs, a major concern in developing the cost estimate is the degree of technical advance sought in a new or modified system. Cost analysts, engineers, and other experts can develop a numerical relationship of the cost of a new or modified system as a function of technical advance or system complexity. For example, the simplest is a zero cost increase if the system is off the shelf, and an incremented percentage increase in the cost (a value judgment by an expert or calculated from past data) if the system requires new technology or major advances in the state of the art.

Cost estimation documentation and use of FAA approved cost models are considerations for identifying and quantifying R,E&D project costs. These topics are discussed below.

Cost Estimation Documentation - Documenting the cost estimation process used is an essential activity specifically required by FAA Order 1810.3. Cost estimation documentation is a detailed written record of data, events, procedures, and analyses used to produce a final cost estimate. This record may describe configurations, development schedules, quantities, conditions, and requirements related to technology, deployment concepts, mission characteristics/requirements, training, logistics, operations, maintenance, and others. Completeness of the estimate is an important objective that requires documenting not only what costs are included, but what costs are excluded. This detailed written record should be included in the formal submission of the benefit, cost, and risk assessment documentation and be used by management during follow-on reviews at each key decision point in the acquisition cycle. Besides the initial cost estimate, cost estimation documentation needs to be updated to include such information as follow-on estimates, cost tracking, periodic and formal reviews, changes in cost estimating personnel, system changes/revisions, and changes in the level of detail of the cost estimate.

FAA Approved Cost Estimation Models - Appendix B lists cost estimation models which are approved for use on FAA projects.

4.0 Risk Assessment Guidelines

Risk[8] is defined as the probability of an undesirable event occurring combined with the consequence of the occurrence. In the context of this document, risk is the probability that a project will fail to deliver the benefits projected for that project, either in whole or in part, and the consequences of this failure. The risk can derive from uncertainties in the project's concept or problems encountered during research, engineering, development, implementation, or operation. Risk is also encountered in non-capital and regulatory projects and should be assessed in a fashion analogous to the risk assessment of development projects. Project risk assessment is not about safety, security or health risks which a project might be aimed at mitigating, but the risk of project completion and obtaining the desired benefits.

4.1 Project Dependencies

In assessing the risk of a program, any linkages of the R,E&D project with other programs must be considered. This must be documented in the risk assessment submission as a statement of project dependencies:

(1) <u>Describe the relationship to other R,E&D, F&E, or O&M projects</u>. Example questions to answer are: is the outcome of this project dependent on input from another project; is this project dependent on support from the performance of another project; or is this project dependent upon the activities of another agency like NASA or DOD. Describe and provide evidence that:

- ⇒ The plans and budgets among related projects are coordinated, or
- ⇒ The R,E&D program has no relationship to other R,E&D, F&E or O&M projects.

(2) <u>Describe follow-on efforts required to implement the results of this R,E&D project</u>. For example, identify any necessary F&E project, publication of an advisory circular, or issuance of a new regulation that may be required to put the results of the R,E&D project into effect or operation. Describe and provide evidence that:

- ⇒ The follow-on efforts are coordinated, or
- ⇒ The R,E&D program has no follow-on efforts.

4.2 Risk Assessment

In these guidelines, a distinction is made between **R,E&D Risk** and **Implementation Risk**. R,E&D Risk is the risk associated with performing the R,E&D project. It does not consider the risks associated with implementing the results of the R,E&D project, which is covered by Implementation Risk. Both the R,E&D Risk and the Implementation Risk are further broken down into ten components, or facets, of risk which are used to assess the overall R,E&D Risk and the overall Implementation Risk. These risk facets have been selected to facilitate the risk

[8] This section draws heavily upon and adapts risk assessment concepts described in *Acquisition and Program Risk Management Guide*, Revision 1, FAA-P-1810, September 29, 1995.

identification and quantification processes. The ten facets of R,E&D Risk and Implementation Risk are defined as follows:

- **Risk$_{\textbf{Technical}}$** is the risk associated with (1) developing a new or extending an existing technology to provide a greater level of performance than previously demonstrated, or (2) achieving an existing level of performance subject to new constraints. For a regulatory project, it is the risk associated with the technical success of the research performed which underlies a new device, procedure, rule or regulation.

- **Risk$_{\textbf{Operability}}$** is the risk associated with how well the system produced operates within the National Airspace System (NAS) or with other systems. It also refers to how well the system operates to design or safety specifications. It addresses NAS or other interfaces, the degree to which they are known and complete, and the degree to which the operational concept has been demonstrated and evolved to the point of a design baseline. For regulatory projects, it is the risk associated with how well the regulation, rule, or procedure, when implemented, works within the NAS context.

- **Risk$_{\textbf{Producibility}}$** are those risks associated with manufacturing and production capabilities. For regulatory projects, this does not normally apply.

- **Risk$_{\textbf{Supportability}}$** considers risks associated with fielding and maintaining the resulting systems. For regulatory projects, this would deal with risks associated with on-going support to the regulatory process, such as inspections or audits.

- **Risk$_{\textbf{Cost}}$** is the risk that considers the likelihood that the project will be completed within the budget specified.

- **Risk$_{\textbf{Schedule}}$** considers the likelihood that the project will be completed within the schedule specified.

- **Risk$_{\textbf{Programmatic}}$** considers the risks of obtaining and using applicable resources and activities which may be outside of the project's control, but can affect the project's direction.

- **Risk$_{\textbf{Managerial}}$** refers to complexity of the project to manage (e.g., number of sub-tasks and/or number of performing organizations) and to management style and continuity.

- **Risk$_{\textbf{Funding}}$** addresses the availability of funds when they are needed and a confidence in management and Congress that those funds will continue to be provided.

- **Risk$_{\textbf{Political}}$** are primarily those risks associated with Congress and their backing of the FAA on-going and in-development systems, programs, regulations, procedures, rules, and products.

The two steps of risk assessment are: (1) **Risk Identification**, and (2) **Risk Quantification**. An overview of the risk assessment process is shown in Figure 4.1. It outlines the steps required to identify and quantify risks, and then relates those steps to various tables in this document. The risk assessment process is performed twice, once for R,E&D risk and once for Implementation risk

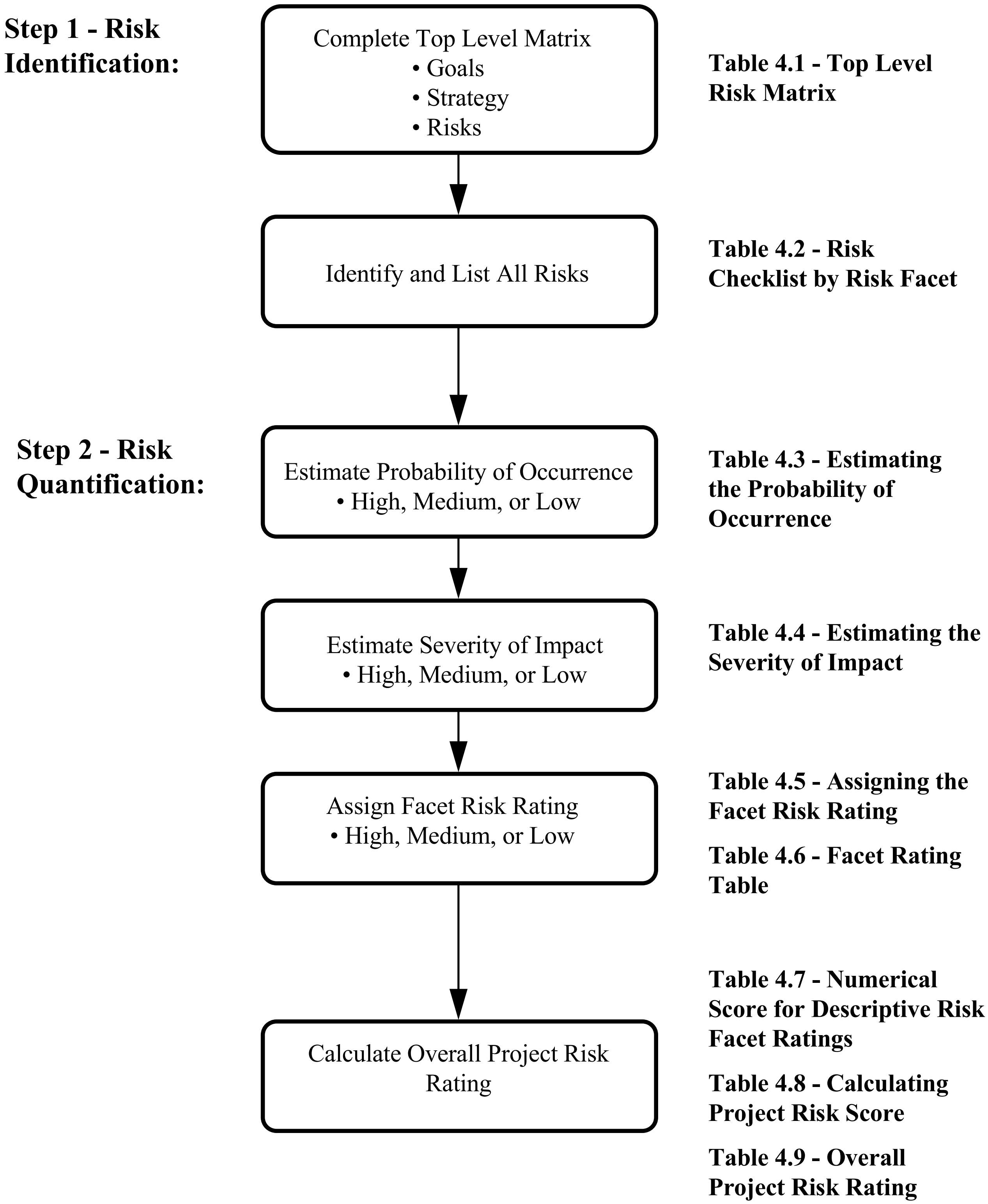

Figure 4.1. Risk Assessment Process

Step 1 - Risk Identification.

Risks cannot be assessed or managed until they are identified and described in an understandable way. Risk identification is an organized and thorough approach to seek out risks associated with a project. It is not a process of trying to invent highly improbable scenarios of unlikely events in an effort to cover every conceivable future possibility.

Step 1 is performed once for R,E&D risk and once for Implementation risk. The same table formats are used for R,E&D and Implementation risk assessments.

A **Top Level Risk Matrix**, Table 4.1, is employed to assure a structured and consistent risk identification process for the ten risk facets and to document the results. All ten risk facets are used for assessing Implementation Risk, and all but the Producibility and Supportability risk facets are used for assessing R,E&D Risk. Completing Table 4.1 to identify risks involves the three steps of (1) Defining Program Goals, (2) Defining Program Strategies, and (3) Identifying Risks. By thinking about and documenting these steps, risks can be identified in a systematic manner. The three steps involve:

> (1) Defining Program Goals - Program goals are defined as they relate to each facet of risk. Goals, or references to goals, should be stated for each risk facet under the R,E&D and Implementation columns in Table 4.1. One would expect this step to be an easy task. More than likely, it will be a thought provoking and controversial process. Requirements specified in the Program Management Plan (if it exists) should be included as goals. If the Plan is missing or is not explicit enough to be included as a goal, this process identifies that fact (which in itself is an important risk reduction action). All goal blocks on the matrix should be covered. A goal block that cannot be filled out to the satisfaction of the program manager is an alert, and the program manager should precipitate some action to fill the void.
>
> (2) Defining Program Strategies - Program strategies represent the plan(s) for achieving the goals for each facet of risk. In the ideal case, the strategy blocks in the matrix in Table 4.1 should contain references to chapters or paragraphs in one or more of the program plans. If this is not the case, the plans may be inadequate. This causes the greatest risk of all: that of not having a plan to reach each risk facet goal. The Top Level Risk Matrix can serve as a forcing function to insure the plans address all goals.
>
> (3) Identifying Risks - A simple first step in risk identification is to identify the risks for successfully completing the strategies for each goal. The very imperfect world of systems acquisition frequently forces the program manager to do things that are counterproductive or sub-optimum, and hence cause risk. Highlighting these anomalies is a powerful contribution to risk identification.

Table 4.1, Top Level Risk Matrix, is presented with examples of project entries in each box to clarify how the table is used. The sample entries are constructed for a possible R,E&D project related to satellite surveillance.

Table 4.1 - Top Level Risk Matrix

RISK FACET		PROGRAM PHASE	
		R,E&D	**IMPLEMENTATION**
Technical	**Goals:**	To provide preliminary evidence in the form of analysis, simulation, and test results that project concepts are technically feasible and satisfy requirements.	To transition from ground-based radar surveillance to a joint satellite and ground-based surveillance system.
	Strategy:	Conduct a set of R,E&D experiments and demonstrations that provide scientific evidence of the concept feasibility.	Develop and implement new technology to provide joint satellite and ground-based surveillance.
	Risks:	• Insufficient ground stations and equipped aircraft to provide conclusive R,E&D results. • Undue reliance on unproved technology.	• Possible inadequate capability of some other related systems planned • Uncertain technical requirements of programs with which new system will interact
Operability	**Goals:**	To demonstrate the capability for system and the existing surveillance system to co-exist during transition.	To provide users and the FAA with operational benefits, such as the implementation of free flight.
	Strategy:	Perform adequate analysis, simulation, and test to demonstrate the feasibility of co-existence during transition.	Determine the surveillance requirements of free flight and other advanced automation programs in order to provide a design that fully satisfies these requirements.
	Risks:	• Insufficient testing • Inaccurate modeling	• Uncertain operational requirements of the other programs
Producibility	**Goals:**	NOT APPLICABLE	To develop and manufacture ground-based and aircraft-based system components to meet requirements and be within the cost estimates.
	Strategy:		Use non-developmental items (NDI) and integrated NDI to the extent possible.
	Risks:		• Excessive specifications which may require custom design & manufacture
Supportability	**Goals:**	NOT APPLICABLE	To provide support for both existing and new surveillance systems during transition to the new system.
	Strategy:		Coordinate closely with AF, including the field, and establish the Project Office within the appropriate Integrated Product Team.
	Risks:		• Satellite support not under FAA control • FAA Logistics Center responsibilities not defined • Existing system may not be maintainable over the implementation period required for new system
Cost	**Goals:**	To accomplish R,E&D required to support system specification decisions within the cost estimates.	To provide users and FAA with benefits, such as free flight within estimated program cost.
	Strategy:	Implement an integrated set of cost controls for each R,E&D project associated with the program.	Implement cost control tools that will be used by the program office
	Risks:	• Cost estimation errors	• Life-cycle costs difficult to estimate • User avionics costs difficult to estimate

Table 4.1 - Top Level Risk Matrix (continued)

RISK FACET		PROGRAM PHASE	
		R,E&D	**IMPLEMENTATION**
Schedule	**Goals:**	To complete the needed R,E&D within estimated schedule.	To fully implement the new system by the year 20XX according to the schedule contained in the program plan.
	Strategy:	Concurrently conduct R,E&D and initial phases of acquisition program.	Initiate the acquisition program prior to completion of all identified R,E&D.
	Risks:	• Schedule sensitivity to technical risk • Contracting process • Excessive task concurrency	• Approval cycles and funding sensitive to political factors • Potential unaccounted contingencies in program schedule
Programmatic	**Goals:**	To establish a program office that will manage R,E&D and implementation.	To implement the system concept such that it fully meets the requirements, cost, and schedule estimates provided in the program plan.
	Strategy:	Prepare briefing to top FAA management and obtain approval.	Implement a program office with separate staff and budget and with the authority and responsibility for implementing new system.
	Risks:	• Changes may be requested by top FAA management • Inadequate program organization	• Inadequate program organization • Personnel unavailability • Uncontrolled requirements changes • Requirements freeze not enforced
Management	**Goals:**	To provide the R,E&D planning, resources, and controls needed to accomplish the R,E&D identified in the program plan.	To provide the implementation planning, resources, and controls needed to accomplish the development and implementation identified in the program plan.
	Strategy:	Integrate the required R,E&D efforts to prove system feasibility.	Establish and maintain a self-sufficient program office.
	Risks:	• Lack of coordination among R,E&D efforts • Large span of control • Inadequate authority over related R,E&D efforts	• Inadequate Program Office staffing • Insufficient resources • Inadequate prioritization by top management
Funding	**Goals:**	To obtain the required R,E&D funding identified in the program plan in a timely manner.	To obtain the required development and implementation funding identified in the program plan in a timely manner.
	Strategy:	Obtain top-management support and early entry into the budget cycle; reprogram available funding where needed.	Obtain top-management support; reprogram available funding to get an early start on the acquisition project.
	Risks:	• Possible inadequate funding • Not top agency priority	• Not top agencies priority
Political	**Goals:**	To coordinate R,E&D results within the FAA, the user community, and internationally to solidify support for new system.	To meet the user demands for more flexibility in flight paths.
	Strategy:	Involve the user/international community in the R,E&D design and evaluation process.	Involve the user/international community in the system design and evaluation process.
	Risks:	• Conflicting priorities from multiple users	• Resistance to avionics requirements • Conflicting user demands and priorities

Once the Top Level Risk Matrix has been completed, a **Risk Checklist**, Table 4.2, should be prepared. The checklist should help identify risks and should contain events or characteristics that may reasonably occur which would prevent or delay the achievement of the program goals in the risk area. Every possible risk related to R,E&D and Implementation for the project should be listed. After listing of all possible risks, those which are extremely unlikely or where the outcome is irrelevant to program goals should be eliminated from the list. The checklist should be directed towards the "show stoppers" that will have a major impact on the program such as impacts on milestones on the critical path.

A sample risk checklist is shown in Table 4.2 which provides a comprehensive list of potential risk areas for each of the ten risk facets. The relevant items in the checklist should be evaluated as part of the risk assessment process as they apply either to systems acquisitions or to regulation development, promulgation and enforcement. Other potential risks not listed in the sample risk check list in Table 4.2 should be added.

Table 4.2 - Sample Risk Checklist by Risk Facet

Technical	Operability	Producibility
Technology Risks • Undue reliance on currently unavailable or unproved technology **System Engineering Risks** • Inadequate functional analysis • Deficient functional allocation • Incomplete integration • Undefined internal interfaces • Vague operational environment • Insufficient requirements analysis • Requirements instability • Immature requirements • Weak failure modes analysis • Requirements not traceable • Safety/security not considered **System Design Risks** • Inadequate capacity • Highly complex • Lack of design details • Insufficient design margins • Immature design • Unsatisfactory growth potential • Undefined physical properties • Unproved technology • Incomplete hardware design • Incomplete software design • Inadequate software tools • Difficulty of real-time, safety critical software development • Immature software language • Ineffective fault detection • Use of unique resources • Complex/incomplete man/machine design • Undefined technical approach **System and Regulations Test Risks** • Inaccurate/simplistic modeling • Insufficient simulation • No/Minimal prototype testing • Incomplete/inadequate test planning • Unsatisfactory OT&E results **Technical Documentation Risks** • Inadequate design documentation • Insufficient test documentation • Ambiguous/incomplete requirements documentation • Undocumented technical details **Regulatory Project Risks** • Inadequate testing •Relies on unproved technology •Unavailable support documentation	**User/Operator Risk** • Uncertain operator requirements • Controversy over user acceptance • Increased workload **System Operation Risks** • Undefined external interfaces • Marginal availability • Insufficient Reliability • Complex man/machine interface • Questionable Usability • Unsatisfactory OT&E results **Systems and Regulations Inter-operability** • Incompatibilities with other NAS systems, regulations or procedures • Places undue loads on other systems or regulations • Results incompatible or inconsistent operation with existing systems or regulations • Unspecified operational interfaces • Marginal inter-operability	**Design Production Risks** • Highly complex design • Undeveloped production requirements • Inadequate built-in test equipment • Non-standard Remote Maintenance Monitoring • Novel/unproved technologies **Manufacturing Risks** • Deficient manufacturing plan • Novel/unproved manufacturing technologies • Speculative manufacturing strategy • Significant special tooling • Undefined tooling requirements • Unclear production requirements • Manufacturing begun before engineering is completed • Unavailable manufacturing facilities • Inadequate quality assurance program • Excessive standards • Equipment unavailability • Inexperienced contractor • Inadequate configuration management process • Insufficient skilled labor • Shallow industrial base **Parts & Materials Risks** • Undefined long lead items • Unavailable gov't furnished equipment • Ineffective incoming materials handling • Unidentified hazardous materials • Parts unavailability **Testing and Documentation Risks** • Inadequate consideration of special test equipment • Insufficient qualification testing • Deficient technical data package • Ineffective factory acceptance test program • Untested design changes

Table 4.2 - Sample Risk Checklist by Risk Facet (continued)

Supportability	Cost	Schedule
O&M Risks • Inadequate O&M concept • Undeveloped O&M strategy • Specialized O&M equipment • Insufficient maintainability • Unsatisfactory maintenance interfaces • Inadequate maintenance procedures • Undeveloped maintenance plan • Unenforced configuration management • Deficient change process • Poor integrity **Logistics Risks** • Insufficient spares planning • Spares unavailability • Difficult to transport to site • Inadequate training • Depot responsibilities unclear **Testing & Support Risks** • Insufficient support equipment • Undeveloped support requirements • Inadequate automated test equipment (ATE) • Unidentified field support requirements • Poor diagnostics • Insufficient testing and support facilities • Unskilled/insufficient manpower **Support Documentation Risks** • Deficient technical data • Faulty maintenance plan • Undefined data rights • Inappropriate release cycle **System Implementation Risk** • Deficient implementation approach • Uncertain transition strategy • Unclear rules and procedures • Insufficient personnel/staffing • Unspecified/inappropriate standards **Regulatory Implementation Risks** • Deficient enforcement procedures • Insufficient/insufficiently trained inspectors • Ambiguous inspection procedures • Unavailable inspection equipment • Exotic special tests equipment needed	**Cost Estimation Risks** • Inadequate estimating tools • Estimation errors • Faulty basis of estimates • Insufficient cost margin • Unrealistic overhead and G&A rates • Relies on scarce resources • Speculative life-cycle costs **Cost Management Risks** • Unsatisfactory cost controls • Insufficient cost monitoring **Cost Sensitivity Risks** • Sensitivity to technical risk • Sensitivity to operability risk • Sensitivity to producibility risk • Sensitivity to programmatic risk • Sensitivity to management risk • Sensitivity to funding risk • Sensitivity to political risk • Sensitivity to supportability risk • Sensitivity to schedule risk **Product Cost Risks** • Undefined gov't furnished equipment • NDI unavailable • Facility unavailable • Inadequate budget for tests • Undefined hardware costs • Hidden software costs • Unaccounted for parts and materials • Undefined regulatory testing costs	**Schedule Estimation Risks** • Inadequate estimating tools • Estimation errors • Faulty basis of estimates • Insufficient schedule margin • Optimistic/pessimistic schedule duration • Inappropriate program schedule **Schedule Dependency Risks** • Unpredictable labor strikes • Improper test scheduling • Excessive task concurrency • Unidentified need for procedures development • Unidentified need for regulations development • Inordinate number of critical path items • Unidentified need for standards development • Uncertainties in contracting process • Uncertainties in contractor stability **Schedule Sensitivity Risks** • Sensitivity to cost risk • Sensitivity to technical risk • Sensitivity to operability risk • Sensitivity to producibility risk • Sensitivity to programmatic risk • Sensitivity to management risk • Sensitivity to funding risk • Sensitivity to political risk • Sensitivity to supportability risk • Materials unavailable • Parts unavailable • Gov't furnished information unavailable • Gov't furnished equipment unavailable • Facilities unavailable • Personnel unavailable • Tools unavailable • Contractor unavailable **Schedule Management Risks** • Unsatisfactory schedule controls • Insufficient program schedule monitoring • Improper contractor/subcontractor schedule monitoring

Table 4.2 - Sample Risk Checklist by Risk Facet (continued)

Programmatic	Management	Funding	Political
Program Planning Risk • Slips in other development or regulatory programs • Potential adverse environmental impacts • Unsubstantiated funding profile • Unsubstantiated manpower requirements • Unidentified personnel skills • Minimal resource alternatives • Other system dependencies • Unexpected regulatory changes **Program Organization Risk** • Ambiguous organizational interfaces • Inadequate program organization • Inadequate contractor organization **Program Implementation Risks** • Cumbersome FAA contracting process • Contractor instability • Personnel unavailability • RFP vague or not address all facets • Deficient change implementation • Insufficient program tools **Program Control Risks** • Inadequate planning for contractor monitoring • Undefined key metrics • Uncontrolled requirements changes • Unenforced requirements freeze • Marginal RFP evaluation • Inadequate tracking systems	**Planning Risks** • Incomplete contingency plans • Inadequate program plans • Deficient risk management plans • Inadequate management approach **Organizing Risks** • Large span of control • Inadequate authority • Undefined responsibilities • Unclear communications • Undefined integration responsibilities **Implementing Risks** • Insufficient management tools • Inadequate program office staffing • Inadequate resource allocation • Deficient personnel management • Lack of coordination • Tenuous top management support **Management Control Risk** • Unformalized/ineffective change management • Unsatisfactory configuration management • Insufficient contract evaluation • Insufficient financial management • Irregular/unscheduled program reviews • Insufficient history/records	**Funding Constraint Risks** • Unfavorable agency priorities • Inadequate funding • Unavailable funding • Lengthy budget cycle • Low OMB marks **Funding Support Risks** • Inadequate user support • Ambiguous operator support • Unclear political support • Marginal cost/benefits • Inconsistent FAA plans **Fiscal Management Risk** • Insufficient funding requirements • Insufficient fiscal controls • Insufficient fiscal tools • Insufficient funding plans • Unrealistic funding profile	**Congressional Based Risks** • Impact of congressional mandates • Unfavorable congressional hearings • Critical GAO reports **Administration Based Risks** • Conflicting FAA priorities • Conflicting DOT priorities **Aviation Community Risks** • Inordinate media attention • Conflicting user demands • Pressure from user groups • Marginal user support • Resistance to regulations

Step 2 - Risk Quantification.

Risk Quantification is the second step in risk assessment. Again, the process in the tables that follow is used for both R,E&D risk and Implementation risk assessments.

The risks identified in Tables 4.1 and 4.2 are used to give a risk rating to each facet of risk and then generate an overall risk rating. In spite of attempts to be analytic about quantifying risks, considerable subjectivity remains. The degree of risk perceived in a given situation is partially a reflection of the personality of the risk assessor. Twenty people can look at the same situation and assign twenty different risk values to it. A **risk rating scheme** built against a set of definitions provides a framework for eliminating some of the ambiguity. Further, the rating scheme should be simple. The following risk rating scheme involves assigning a High, Medium, or Low rating using the notion that the degree of risk is a judgment reflecting the probability of occurrence and the severity of impact.

For each risk facet, risk quantification involves: (1) estimating the probability of occurrence of an adverse event (expressed as High, Medium, or Low) using Table 4.3 and entering the result in the second column of Table 4.6; (2) estimating the severity of the impact of the adverse event (expressed as High, Medium, or Low) using Table 4.4 and entering the result in the third column of Table 4.6; and (3) assigning a Facet Risk Rating using the assignment scheme shown in Table 4.5 and entering the result in the last column of Table 4.6.

Three methods to estimate the probability of occurrence and severity of impact are: (1) Expert Interviews; (2) Analogy Comparisons; and (3) Evaluation of Program Plans. Each of these is briefly described below.

> (1) Expert Interviews - This process involves identifying expert(s) and methodically questioning them about the risks in their area of expertise as related to the R,E&D project. Data collection sheets (as defined in Reference 13) can be used to facilitate this process. The interviews focus on extracting information about what the program risks are and their relative magnitude.
>
> (2) Analogy Comparisons - The analogy comparisons and lessons learned techniques for risk identification and quantification are based on the idea that no new program, no matter how advanced or unique, represents a totally new concept or system. The process involves review and use of data from similar prior programs as the basis for risk quantification on the subject program.
>
> (3) Evaluation of Program Plans - This technique highlights and isolates risks caused by insufficiencies and disparities in planning. It evaluates program plans for contradictions and voids. The plans do not need to be formal plans, but could include program management plans, acquisition plans, specifications, statements of work, or work breakdown structures. The process assesses the plans for correctness, completeness, currency, and consistency.

Table 4.3 - Estimating the Probability of Occurrence

Facet Impacted	High Probability of Occurrence	Medium Probability of Occurrence	Low Probability of Occurrence
Technical	Design unknown. Approach to meet requirements or regulatory development carried only through conceptual design and analysis. Technology is only concept or experimental.	Design is in development or prototype phases. Technology prototype or engineering model tested in relevant environment but not operated in fielded environment.	Design is mature. Technology within state-of-the-art or off the shelf. Performance specifications are known.
Operability	NAS or other interfaces not fully known or documented. Operational concept or implementation of concept has yet to be established. Will cause significant impact to procedures and could cause operational implementation to be unsuccessful. Implication of regulations on other systems has not been examined or considered.	NAS or other interfaces somewhat known and partially documented. Operational concept has evolved to the point of a design baseline. Will impact several procedures and may cause operational implementation to be unsuccessful. Impact analysis of proposed regulation on other NAS elements has been initiated but results are not complete or are inconclusive.	NAS or other interfaces are known and documented. Design approaches for the operational concept have been demonstrated or implemented. Will impact a few procedures but operational implementation is expected to be successful. Regulatory impact analysis has been completed and the results are favorable.
Producibility	Manufacturing and production processes not known or unavailable.	Manufacturing or production process in state of change.	Manufacturing and production capabilities known and available.
Supportability	Similar items have been developed but not fielded. Substantial modifications to existing technologies, regulations, or procedures, together with new support technologies and procedures will be required and could prevent suitable transition of support to AF. Regulatory enforcement procedures have not been developed or considered.	Items similar in concept have been supported as fielded systems or supported during test. Substantial modifications may be required to existing support technologies, regulations, or procedures and transition of support to AF may be difficult. Procedures for enforcement of regulations have been initiated but are not complete and have not been tested.	Similar item has been fielded & is currently being supported, or has been demonstrated to be sup-portable during field testing. Only minor changes to existing support technologies, regulations, or procedures will be required. Transition of support to AF will be successful. Procedures for regulatory enforcement are complete & have been tested; results are favorable.
Cost	Basis for cost estimation is inadequate, or major uncertainties exist related to the scope/definition required for estimation.	Cost factors not certain, but scope/definition required for estimation is adequate.	Cost factors understood and based on or extrapolated from similar items in production. Definition required for estimation is adequate.
Schedule	Many schedule interdependencies for which there is little or no flexibility to absorb delays. Few or no plans to minimize unknowns; difficult or complex system to develop. Knowledge and experience base very limited.	Some schedule interdependencies with little schedule margin. Plans to minimize unknowns are generally complete; some uncertainties exist. Little knowledge and experience in some areas.	Adequate schedule with substantial margins and achievable plans to minimize unknowns. High knowledge and experience base. There are no schedule dependencies beyond the control of the project.
Programmatic, Managerial, Funding and Political	Programmatic, managerial, funding and political facets and environments not known or unstable.	Programmatic, managerial, funding and political facets and environments in state of change but somewhat known.	Programmatic, managerial, funding and political facets and environments known and stable.

Table 4.4 - Estimating the Severity of Impact

Facet Impacted	High Severity of Impact	Medium Severity of Impact	Low Severity of Impact
Technical	Performance or problem data indicate that with current project design margins, full performance unlikely to be met and alternate system or regulatory approaches are not available.	Performance or problem data indicate that with current project design margins, full performance objectives will only be met by: (1) significant modification to a design of a component or subsystem; or (2) reallocation of design margins among subsystems.	Performance and problem data indicate that only minor hardware/software design changes will be needed to meet full performance and/or regulatory objectives.
Operability	No operationally suitable technical or regulatory solutions available without major impacts on the overall system performance. Will cause significant impact to existing procedures and could cause operational implementation to be unsuccessful. Implication of regulations on other systems has not been examined or considered.	Technical or regulatory operationally suitable solutions partially identified. The solution is not readily available or will have significant impacts on the overall system performance. Will impact several procedures and may cause operational implementation to be only partially successful. Impact analysis of proposed regulation on other NAS elements has been initiated, but results are not complete or are inconclusive.	Technical or regulatory operationally suitable solution is identified and readily available. Will impact a few procedures but operational implementation is expected to be successful. Regulatory impact analysis has been completed, and the results are favorable.
Producibility	Manufacturing and production processes not known or unavailable.	Manufacturing or production process in state of change.	Manufacturing and production capabilities known and available.
Supportability	System design characteristics & planned logistics and S/W support resources do not meet system utilization requirements. Support procedures, regulations, or technologies will be significantly impacted and could prevent suitable transition of support to AF. Enforcement of the proposed regulation is unlikely to be feasible.	System design characteristics & planned logistics and S/W support resources meet some but not all system utilization requirements. Some support procedures, regulations, or technologies will be impacted and transition of support to AF may be difficult. Enforcement of the proposed regulation is questionable or uncertain.	System design characteristics & planned logistics and S/W support resources meet nearly all system utilization requirements. Only minor support procedures, regulations, or technologies will be impacted, and transition of support to AF highly likely to be successful. Enforcement of the proposed regulation is feasible and has been demonstrated in similar situations
Cost	>$5 Million potential impact to project costs; or Contractor costs likely to exceed contract maximum; or operations and maintenance cost maximum likely to be exceeded.	$1-5 Million potential impact to project costs; or Contractor costs likely to exceed the contract target cost; or estimated operations and maintenance cost likely to be exceeded by 5%, but not exceed the respective maximum costs.	<$1 Million potential impact to project costs; or Contractor costs not likely to exceed the contract target cost; or estimated operations and maintenance support cost not likely to be exceeded by more than 5%.
Schedule	A schedule slip of more than three months is expected to severely impact major milestones.	A schedule slip of one to three months is expected to impact major milestones.	A schedule slip of less than 1 month is expected, and the schedule delay can be managed within the schedule or cost target for that element.
Programmatic, Managerial, Funding and Political	Programmatic, managerial, funding and political facets and environments not known and may severely impact the technical or regulatory project.	Programmatic, managerial, funding and political facets and environments in state of change but somewhat known, and may significantly impact the technical or regulatory project.	Programmatic, managerial, funding and political facets and environments known and stable, and may insignificantly impact the technical or regulatory project.

Table 4.5 - Assigning the Facet Risk Rating

Risk Probability	Risk Severity	Facet Risk Rating
High Medium High	High High Medium	High High High
Low Medium High	High Medium Low	Medium Medium Medium
Low Medium Low	Medium Low Low	Low Low Low

Table 4.6 - Facet Rating Table

Facet	Risk Probability	Risk Severity	Facet Risk Rating
Technical			
Operability			
Producibility (Not applicable to R,E&D phase)			
Supportability (Not applicable to R,E&D phase)			
Cost			
Schedule			
Programmatic			
Managerial			
Funding			
Political			

The final step is assigning an overall risk rating for the project using a "weighted average" of the ten facet risk ratings. In order to calculate the weighted average risk rating for the project, a numerical score must be assigned to the descriptive (i.e., High, Medium, and Low) facet risk ratings. The numbers in Table 4.7 are assigned to the High, Medium, and Low descriptive risk ratings for this purpose.

Table 4.7 - Numerical Score for Descriptive Risk Facet Ratings

Descriptive Facet Rating	Numerical Score
High	0.8
Medium	0.5
Low	0.2

The Risk Facet Rating from the last column in Table 4.6 is entered into the second column of Table 4.8. The equivalent numerical score for each risk facet rating can then be entered into the third column of Table 4.8 using Table 4.7.

Next, a weight must be assigned to each of the ten risk facets (there are 8 risk facets for R,E&D phase since producibility and supportability are not applicable to R,E&D), based upon the perceived significance of the risk facet to the overall project. The weights should be between zero and 1.0 and the sum of all the weights should be 1.0 (a weight of zero means that that risk facet does not apply and a weight of 1.0 means that only that facet applies). The weights are entered into the fourth column of Table 4.8. The weighted Facet Score for each risk facet is entered into the last column of Table 4.8 by multiplying the entries in the third and fourth columns. The overall weighted average project risk score is entered in the bottom row of Table 4.8 by adding the individual weighted risk facet scores in the last column.

Table 4.8 - Calculating Project Risk Score

Facet Rating	Facet Rating (H, M, or L)	Facet Score (.8, .5, or .2)	Facet Weighting (0-1)	Weighted Facet Score (0-1)
Technical				
Operability				
Producibility (Not applicable to R,E&D phase)				
Supportability (Not applicable to R,E&D phase)				
Cost				
Schedule				
Programmatic				
Managerial				
Funding				
Political				
Overall Weighted Project Risk Score				

Once the weighted average project risk score is calculated, a descriptive project risk rating (i.e., High, Medium, or Low) is assigned using Table 4.9

Table 4.9 - Overall Project Risk Rating

Overall Rating (Score)	Description
High (.7 - 1.0)	Projects with High Overall Risk Rating should receive close attention. Risk facets with High Risk Ratings must be ranked as Principal Risks. Each High Risk must have candidate strategies, metrics and a plan of action and milestones developed by the risk owner and must be aggressively managed. They must be managed on a continuous basis and monitored until the risk is mitigated to an acceptable level.
Medium (.4 - .6)	Projects with a Medium Overall Risk Rating require attention. Risk facets must be examined to see if any are rated high and should be placed on the Principal Risk List and managed as described above. Each Medium Risk must have candidate strategies, metrics and a plan of action and milestones developed by the risk owner and must be managed and reviewed frequently. Any risks on the Principal Risk List must be aggressively managed on a continuous basis and monitored until the risk is mitigated to an acceptable level.
Low (0 - .3)	Projects with a Low Overall Risk Rating do not normally require attention for risk. However, status should be reviewed periodically by the risk owner. Any high or medium risk facets should receive attention as described above.

By conducting the risk assessment process for both R,E&D and Implementation risk, and using Tables 4.3 through 4.9 twice, overall Project Risk Ratings for the R,E&D phase and Implementation phases are obtained.

Use of Outputs of the Risk Assessment Process -- Once the risk assessment process has been completed for rating the R,E&D project risk, the Top Level Risk Matrix, Table 4.1, with all of its supporting documentation, will continue to serve as a basis for monitoring and managing the risk as the R,E&D project is being conducted. The Top Level Risk Matrix should be used to prepare a Risk Watchlist to serve as a worksheet for managers to use for recording risk management progress. The Risk Watchlist provides a convenient and necessary form to track and document activities and actions resulting from managing the risk.

Appendix A - References

References for benefit, cost, and risk analysis methodologies and for approved data values (e.g., value of time, cost of injury, aircraft damage cost, etc.) for these analyses are listed in this appendix.

1. *Economic Analysis of Investment and Regulatory Decisions – Revised Guide*, FAA APO-98-4, January 1998. This handbook provides a systematic approach to answering two fundamental economic questions: (1) what objectives should be pursued; and (2) how should these objectives be accomplished. It provides the steps involved in the economic analysis process. Techniques are developed for measuring such benefits as improved safety, delay reductions, cost savings, as well as others. Cost estimation methodology is presented. It also provides an explanation of the concepts of discounting, present value, and inflation. The purpose of sensitivity analysis is also discussed.[9]

2. *Transition Plan, Redefining CBA Roles and Responsibilities*, Version 2, Program Analysis and Operations Research, FAA, September 14, 1995. This document provides guidance, benefit breakdown structure, and cost breakdown structures for estimating benefits and cost as part of a benefit-cost study. References, models and databases for such studies are described.

3. *Cost Estimation Policy and Procedures*, FAA Order 1810.3, May 15, 1984. This document provides the cost estimation policies which must be followed for FAA major system acquisitions. It provides the life-cycle cost breakdown structure to be used including the definition of recurring and non-recurring elements. It also provides the submittal format which APO requires.[13]

4. *Guidelines and Discount Rates for Benefit Cost Analysis of Federal Programs*, OMB Circular A-94, October 1992. Circular A-94 provides guidance on benefit/cost, cost-effectiveness, and lease-purchase analysis to be used by Agencies in evaluating Federal activities. It includes updated guidance on discount rates to be used in evaluating activities with benefits and costs distributed over time. It also contains expanded guidance on the measurement of benefits and costs, treatment of uncertainty, and related issues.[13]

5. *Regulatory Program of the United States, "Regulatory Impact Analysis Guidance,"* Appendix 5. This document provides guidelines for determining the costs and benefits associated with proposed regulatory proposals.[13]

6. *Terminal Area Forecasts*, FY 1993-2010, FAA-APO-94-11, September 1994. This document contains forecasts of aviation activity of 875 airports in the United States for

[9] This description of the reference cited is from *Transition Plan, Redefining CBA Roles and Responsibilities*, Version 2. Program Analysis and Operations Research, FAA, September 14, 1995.

the years 1993-2010. These include the 401 airports with FAA air traffic control towers and radar approach control services and 29 FAA contract towers. For each airport, detained forecasts are made for the four major users of the air traffic system: air carriers, air taxi/commuters, general aviation, and the military. Summary tables contain national, FAA regional, and state aviation data and other airport specific highlights. The forecasts were prepared to meet budget and planning needs of the FAA and to provide airport-specific information that can be used by State and local aviation authorities, the aviation industry, and the general public.[10]

7. *Economic Values for Evaluation of Federal Aviation Administration Investment and Regulatory Programs*, FAA-APO-98-8, June 1998. Drawing on economic theory, empirical investigations and data from government, private and academic literature, this document revises economic values commonly used by the FAA in the evaluation of investment and regulatory programs. These include the value of time in air travel, the value of a statistical life, unit costs of statistical life, unit costs of statistical aviation injuries, aircraft capacity and utilization factors, aircraft variable operation costs, unit replacement, and restoration costs of damaged aircraft, weight penalty costs, and probabilities of third party damage. These values, often referred to as “critical values,” provide the basis upon which the effectiveness of the aviation system or changes therein may be denominated and assessed in monetary terms.[14]

8. *Treatment of the Values of Life and Injury in Economic Analyses*, FAA Bulletin APO-95-1, March 1995. This bulletin addresses the treatment of values of life and injury in economic analyses. It supplements values contained in FAA-APO-89-10.[14]

9. *Defense Communications Agency Cost and Planning Factors Manual*, DCA Circular 600-60-1. Based on actual costs incurred in the communications projects implemented by the military, this document provides cost estimating factors that can be used to estimate work breakdown structure elements when costs are not readily available.[14]

10. Seiler, Karl, *Introduction to Systems Cost-Benefit-Effectiveness*, Intelligent Choice, Alexandria, VA, 1993. Written by a former FAA economist. Describes the structure of suitable system cost models, structure of benefit models using positive and negative cash flows, structure of an effectiveness model based on system performance parameters, availability, reliability, and survivability. Also combines these models into an overall system comparison mode.[14]

11. Gramlich, Edward M., *Benefit-Cost Analysis of Government Programs*, Prentice Hall, Inc., 1981. This is the first edition of a textbook which addresses benefit-cost analysis. It show the logic of benefit-cost analysis and how it can be applied to a wide range of policy measures. It provides explanations of economic principles in a way that

[10] This description of the reference cited is from *Transition Plan, Redefining CBA Roles and Responsibilities*, Version 2. Program Analysis and Operations Research, FAA, September 14, 1995.

can be easily understood, even by those individuals not having a background in economics.[11]

12. Gramlich, Edward M., *A Guide to Benefit-Cost Analysis*, Prentice Hall, Inc., 1990. This the second version of the "Benefit-Cost Analysis of Government Programs." It updates the information, adds additional material, and brings in new examples.[15]

13. *Acquisition and Program Risk Management Guide*, Revision 1, FAA-P-1810, September 29, 1995. A draft report. Prepared by Air Traffic Systems Development, Office of Business and Financial Management, AUA-10. An adaptation of a DOD risk assessment methodology documented in a report by the Defense Systems Management College, Ft. Belvoir, VA.

14. *FAA Air Traffic Activity, Fiscal Year 1994*, FAA APO-95-11. This document provides terminal and en route air traffic activity information. The data is reported by the FAA-operated Airport Traffic Control Towers (ATCTs), Air Route Traffic Control Centers (ARTCCs), Flight Service Stations, Approach Control Facilities, and FAA-contracted ATCTs.

[11] This description of the reference cited is from *Transition Plan, Redefining CBA Roles and Responsibilities*, Version 2. Program Analysis and Operations Research, FAA, September 14, 1995.

Appendix B - Databases, Models and Analysis Tools

This appendix lists data sources, models and analysis tools that can support benefit, cost, and risk analyses.

B.1 Sources of Approved Values for Benefit Estimation

Benefit Category	Source of Approved Values
Safety Benefits	Value of fatality, injury, aircraft damage: Ref. 1, 7, & 8 Projections of future flight activity: Ref. 6
Security Benefits	Value of fatality, injury, aircraft damage: Ref. 1, 7, & 8 Projections of future flight activity: Ref. 6
Delay (Users) Benefits	Value of passenger time: Ref. 1&7 Hourly aircraft operating cost: Ref. 1&7
Efficiency (Users) Benefits	Value of passenger time: Ref. 1&7 Hourly aircraft operating cost: Ref. 1&7
User Capital Costs Avoided	
FAA Productivity Benefits	
FAA Capital Costs Avoided	
Enabling Technologies	Sources from other benefit categories should be used as appropriate.
Society Benefits	

B.2 Databases

The following databases may be of use in performing benefit and cost analyses.

Database Name	Responsible Office	Database Description
FMF & PFF	AOP-200	Facility Master File and Precomissioned Facility File - Databases from Facility/Service/Equipment Profile (FSEP) module of Maintenance Management System (MMS) containing information on FAA facilities and equipment from pre-construction through decommissioning.
PCFMF & PCPFF	AOP-200	PC version of facility master file and pre-commission facility file.
TIMS	AOP-600	Telecommunications Information Management System contains an inventory of telecommunications circuits and equipment.
EDB	FAALC	Engineering Data Base - End-state FAA system locations showing latitudes, longitudes, controlling ACF, antenna height, source/sink of functional interface, and specific subsystem connectivity.
F&E BSL	ASD-300	Facilities & Equipment Financial Baseline - Contains the financial baseline of F&E costs for current CIP projects.
CBAS	ASD-400	Cost Benefit Analysis System - Contain information on present and future costs and benefits of CIP projects to users and FAA.
NAPRS	AOP-200	National Airspace Performance Reporting System - Facility and service reports on scheduled and unscheduled outages, operational availability, operational delays and causes of delays.
TAF	APO-110	Terminal Area Forecasts - Forecasts of aviation activity at over 800 airports in the US.
OAG	APO-130	Official Airline Guide - Schedules of airline arrivals and departures.
OPSNET	ATM-300	Operational Performance System Network - Includes delays of 15 minutes or more in departure and arrival queues and en route. Includes air carrier, air taxi, general aviation and military flights along with cause of delay. Also, includes monthly traffic counts for 55 major airports.
ASQP	DOT	Air Service Quality Performance System - On-time performance reporting system. Provides actual versus scheduled times for departure time, wheels-up time, wheels-down time, and arrival time for airlines with 1% or more of traffic.

Database Name	Responsible Office	Database Description
ETMS	ATO	Enhanced Traffic Management System contains flight data messages (for IFR flights) from host computers.
ACARS	ATO	Air Transport Association provides a monthly report to FAA on delays by phase of flight derived from Aeronautical Radio, Inc., Communications and Reporting System.
NAIMS	ASY	National Airspace Incident Monitoring System - Contains NMACS, PDS, OEDS, VPDS, and RI (described below).
NMACS	ASY	Near Mid Air Collision System reports in-flight incidents where two aircraft have closed to an unsafe distance and avoided an actual collision as reported by aircrew members.
PDS	ASY	Pilot Description System records information about reported incidents in which the actions of the pilot violate a Federal Aviation Regulation (FAR) or a North American Aerospace Defense Command (NORAD) Air Defense Identification Zone (ADIZ) tolerance.
OEDS	ASY	Operational Errors & Deviation System reports situations which do not actually result in a collision but meet specific criteria as posing a potential danger or violating operational guidelines.
VPDS	ASY	Vehicle/Pedestrian Deviation System reports pedestrians, vehicles, or other objects interfering with aircraft operations on runways or taxi ways.
RI	ASY	Runway Incursions is derived from OED, PDS and VPDS systems.
ASRS	ASY	Aviation Safety Reporting System - Contains operational errors, pilot deviations, and other air traffic problems voluntarily reported by pilots and controllers.
NTSB AAD	NTSB	NTSB Aviation Accident Database - Provides characteristics of all accidents, including the sequence of events that occurred in the US airspace and summary narratives of each accident.
AIDS		Accident and Incident Data System contains data on general aviation accidents/incidents, air carrier incidents, and beginning with 1982, air carrier accidents. Data from NTSB and FAA accident and incident forms.
SDRS	Flight	Service Difficulty Report System deals with conditions adversely

Database Name	Responsible Office	Database Description
	Standards Service	affecting continued airworthiness of aeronautical products, through the collection of Service Difficulty and Malfunction or Defect Reports; their consolidation & collation in a common data bank; analysis of that data; and dissemination.

B.3 Cost Estimation Models

The following models may be of use in performing life-cycle analysis. For some models licenses must be procured; others are available through the government.[12]

Model Name	Description
PRICE-H	Parametric Review of Information for Costing and Evaluation - A model used for deriving cost estimates of electromechanical hardware assemblies and systems.
PRICE-HL	Parametric Review of Information for Costing and Evaluation - A model used for deriving life-cycle cost estimates of electromechanical hardware assemblies and systems.
PRICE-S	Parametric Review of Information for Costing and Evaluation - A model used for deriving life-cycle cost estimates for software systems.
PRICE-M	Parametric Review of Information for Costing and Evaluation - A model used for deriving cost estimates of microcircuits.
FLAPS	FAA Lincs Architecture Pricing System - Estimates the recurring and non-recurring costs of leased communications lines under the LINCS contract with MCI.
AFCE	Airway Facilities Cost Estimation Model - A derivative of the DOD CASA model (described below) specially tailored for use in estimating life-cycle costs of FAA systems.
CASA	Cost Analysis Strategy Assessment - Estimates life-cycle costs, analyzes production rate and quantity variation, determines warranty costs and operational availability, and performs several other related functions. Developed for use in DOD.
COCOMO	Constructive Cost Model
ACEIT	A cost-estimating tool developed for use in DOD. Uses a spreadsheet style structure to develop cost breakdown structures and contains an automated database of cost estimating relationships developed from industry data.

[12] The descriptions of models are from *Transition Plan, Redefining CBA Roles and Responsibilities*, Version 2. Program Analysis and Operations Research, FAA, September 14, 1995.

B.4 Analysis Tools

The following are computer-based analysis tools that can be used to aid benefit and cost analyses. For some tools licenses must be procured; others are available through the government.

Model Name	Description
@RISK	A spreadsheet tool for conducting risk assessments using Monte Carlo or Latin Hypercube sampling techniques to simulate user defined probability distributions of cost and benefits.
EXPERT CHOICE	An analytic hierarchy process for multiple criteria decisions.
SPSS	A statistical analysis software tool providing extensive data management, exploratory data analysis and statistics with ANOVA, cluster, correlation, factor, non-parametric, regression, t-tests and reliability measures. Many other advanced statistical analysis tools are contained in SPSS.